

Advancement of CAD/CAM in Prosthetic Dentistry: A Review

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Abstract—Constant advancements in Computer Aided Designing/Computer Aided Manufacturing(CAD)/(CAM) technology played a significant role for its successful implementation in dentistry. Initially, prostheses fabricated by CAD/CAM technology were costly and technique sensitive, but nowadays, because of advancements in CAD/CAM technology, makes digital dentistry more popular and extensively usable. In recent phase, dental CAD/CAM systems are being used not only for automated prosthesis fabrication but also for patient's comfort and to reduce chair side time. This paper reviews the evolution of the CAD/CAM system and its applications in the field of dentistry over decades.

Keywords: CAD/CAM, Digital dentistry, Prosthodontics, Restoration.

1. INTRODUCTION

For last 30 years, CAD/CAM technology has revolutionized various manufacturing sectors including 'Dentistry' as one of them. Ever since the introduction of CAD/CAM in dentistry, there has been a constant phase of advancement to the technology. In dentistry, CAD/CAM technology not only reduces the human efforts but also eradicates many manufacturing errors induced in conventional methods. Recent dental CAD/CAM systems are able to fabricate the prostheses directly from the data obtained from the patient's mouth. However, the current status of CAD/CAM in dentistry is limited to laboratory processing but its advantages will ultimately benefit the patients.

2. HISTORICAL BACKGROUND AND CURRENT STATUS

In early 1970s, Duret and colleagues introduced the CAD/CAM to the dentistry. They developed the Computer aided system for dental restorations. In this process the intra-oral digitizer was used for scanning of intra oral abutment and a numerical controlled machine was used to mill the block. Later, Duret developed the commercial Sopha system but it obsolete soon without impact on dentistry [2].

In 1979, Heiliger and Rodder, followed by Moermann and Brandenstini in 1980, contributed to the CAD/CAM dentistry. Moermann developed the CEREC (Chairside Economical Restoration of Aesthetic Ceramic) system and succeed in inlay restoration fabrication by digitizing inlay cavity directly in the mouth, using a compact intra oral camera, which is less difficult compared with Crown abutment. CAD/CAM became popular in dentistry with introduction of CEREC system through work. However, initial development of CEREC was innovative chair side system, but the application was limited to ceramic inlay restorations and occlusal and contour was initially not available [2-4].

In 1980s, many researchers worldwide approached the Duret laboratory system information and begun to develop a system to fabricate a crown with an anatomical occlusal surface. In 1983, first CAD/CAM prototype was presented at the Garanciere conference, France. Not too late, 1985 was a decisive year for computer aided dentistry, as first crown was publicly milled and installed in mouth without any laboratory help [2].

Earlier CAD/CAM systems were not capable to scan and read the soft tissues and intra oral relationship, hence fabrication of complete and partial dentures was not possible and these systems were limited to fabricate the fixed restorations such as inlays, onlays, crowns and bridges. Because of rapid advancements and development in CAD/CAM technology, available dental CAD/CAM systems not only used for fabrication of complete and partial removable dentures (Briefly discussed in table 1) but also for soft tissues replacement and surgical guide [20-23].

Inlays	Inside the tooth
Onlays	Over the tooth
Veneers	Coping covered with ceramic layer
Copings	Dental Crown
Substructures	Two or more Crowns
Full coverage crowns	Complete dentures

3. DENTAL CAD/CAM PROCESS

All CAD/CAM systems consist of three main components.

Scanner: A digitalization tool that transform the present geometry into digital data that can reprocessed by the computer.

CAD Unit: A software unit that reconstructs the 3D geometry and morphology of the restoration or create tool path for fabrication of restoration.

CAM Unit: A production technology that transforms data set into the desired product.

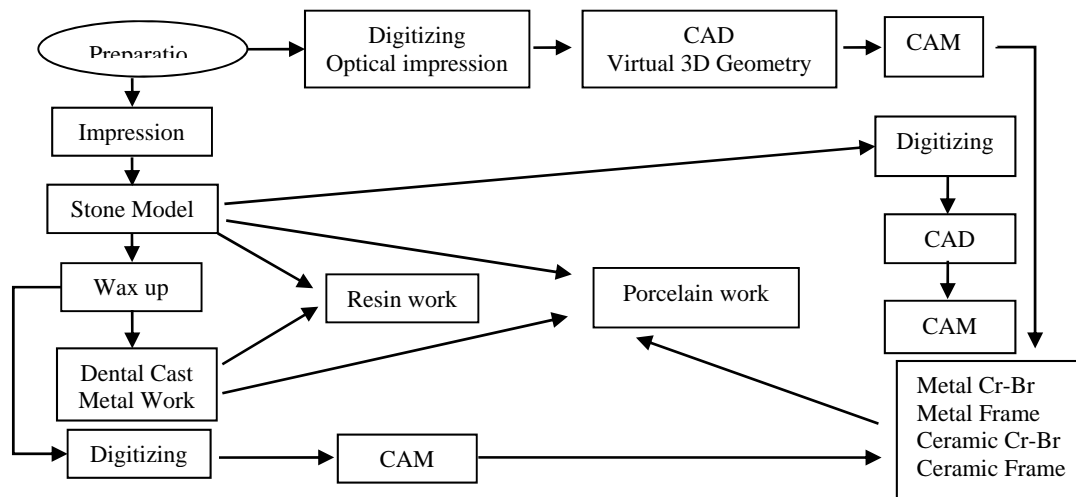


Fig. 1: Overview of CAD/CAM Process

4. DENTAL CAD/CAM APPROACHS

Based on location of CAD/CAM components and on their fabrication process steps, there are three way of production using CAD/CAM.

1. Chair side approach: All CAD/CAM components are located in Dentist's office near to surgery chair. Using this approach dentist can fabricate the restoration and rehabilitate the patient within single appointment. CEREC developed by Mr. Moermann team was first chair side CAD/CAM system and still now, CEREC (sirona) is most widely used CAD/CAM system. E4D (D4D) CAD/CAM is also example of chair side system.
2. Lab side approach: Lab side approach is indirect production method and also known for dentist and laboratory communication approach. Dentist takes impression for restoration and sends it to the laboratory, where master cast is prepared using this

impression. Then master cast transforms into digital data by scanning and remaining fabrication steps carried out on CAD/CAM system. Celay system is kind of the lab side production approach.

3. Centralize approach: The third way of computer aided fabrication of restoration is centralize CAD/CAM system. Centralize fabrication approach can also be termed as, CAD/CAM for outsourcing dental lab work using network. The central milling unit is connected with various dental labs. Scanning and 3D virtual modeling steps are processed in dental labs and data send to the central milling unit, where restorations are fabricated. Procera system makes this approach possible.

5. DEVELOPMENT IN DENTAL CAD/CAM SYSTEMS

Based on deferent dental CAD/CAM approaches, various CAD/CAM systems have been developed (Reviewed in table 2) since introduction of CAD/CAM in dentistry. Some of them are discussed below.

- CEREC system: CEREC stands for “Chairside Economical Restoration of Aesthetic Ceramic”. The first phase of CEREC (CEREC 1) system developed by Siemens Corporation was introduced in 1980. Later they develop CEREC 2 system in 1994, and third generation of CEREC (CEREC 3) system brought by Sirona, Benheim, Germany in 1999. CEREC (sirona) system has several technical advantages over CEREC 2, including the 3D intra oral camera, manipulation of the picture, and the grinding unit [4, 9].
- Procera system: First Procera system was designed by Dr. Anderson in 1987. However, fabrication of titanium coping by Spark erosion were attempted initially but later this system was used around the world for fabrication of All ceramic framework for long time. The current Procera All ceram system developed by Noyal pharma, Inc., Goteborg, Sweden, was introduced in 1994. It consists Electric discharge machined used for ceramic copings fabrication [27, 28].

Table 2: Review of CAD/CAM systems
(I – Inlays; O - Onlays; C – Crowns; V – Veneers; *Cerec 2 and 3 only)

Production method	System	Scanning method	Restoration produced	Remarks
Direct in-office	Cerec 1 Cerec 2 Cerec 3	Laser	Ceramic I/O/C*/V*	Widely used
	Sopha	Laser & holography	Ceramic I/O/C/V	Lengthy design and manufacture
	Denticad	Contact probe	Ceramic I/O/C/V	Most automated
Indirect in-office	Celay	Contact probe	Ceramic I/O/C/V	Copy milling only
Dental laboratory	Dux (Titan)	Contact probe	Titanium substructures	Requires esthetic veneering
	Denti CAD	Contact probe	Ceramic I/O/C/V	Mills wide variety of materials
	Cicero	Laser	Ceramic crowns	Built in veneering
	LAVA	Laser	Ceramic copings	Requires esthetic veneering
	Everest	Optical scanner	Ceramic copings	Mills up to 16 units at once
Indirect industrial for outsourcing using networks	Procera	Contact probe	Ceramic copings	Requires aesthetic veneering

- Dux system: The Dux system, also known as the Titan system developed by DSC Dental, Allschwill, Switzerland, consisted of a precision contact digitizing sensor a ached to a computer system and a milling machine [7].
- Celay system: The Celay system developed by Mikrona Technologic, Spreitenbach, Swizerland in 1990 was a very small unit. It consisted of a contact digitizer that records the shape of an acrylic inlay and directly transfers the shape to a milling machine [7].
- CICERO system: The computer integrated crown reconstruction (CICERO) system was developed by CICERO Dental System B.V. (Hoorn, The Netherlands). It includes optical scanning, metal and ceramic sintering and computer assisted milling to obtain restoration. Basic reconstruction includes layered life like ceramic for natural esthetics, a precision milled occlusal surface and a machined high strength ceramic core [14].

- LAVA system: Lava CAD/CAM System was introduced in 2002. It has been used for fabrication of zirconium frameworks in all ceramic restorations. The Lava system utilizes yttrium stabilized tetragonal zirconium poly crystals which has a greater fracture resistance than the conventional ceramics. Lava system uses a laser optical system to digitize information [8].

6. DEVELOPMENT IN MATERIALS FOR DENTAL CAD/CAM

Over the years, metals such as Gold have remained first choice for fractured or lost tooth for long time around the world. Sudden rise in gold price during 1980s, obsolete the gold alloys from dental industry. Titanium succeeded the gold but metal allergy and esthetic issues were major consideration to change the metals with other materials for dental prostheses. Recent development in material science and introduction of CAD/CAM made possible application of high strength and excellent in esthetic biomaterials for dental restorations because they can't be transformed into desired shape by conventional 'Lost Wax Method'. In current, high strength ceramics are widely used materials for dental restorations around the world (Table 3, reviewed the material development in CAD/CAM dentistry)[6, 23-25].

7. DISCUSSION AND FUTURE PROSPECTS

In dentistry, significant advancements have been measured since genesis of tooth replacement occurred. In recent, metal alloys prostheses have been replaced with high strength, excellent esthetic, and biocompatible ceramics. Each of advancements has marked a scope for

Table 3: Materials used in CAD/CAM Dentistry

Name	Manufacturer	CAD/CAM System	Description
CAD-Wax	Vita	inLab	Filler-free acrylic polymer for LWT
Cercon base cast	Degu Dent	Cercon	Residue-free cauterizable resin for LWT
Everest c-cast	KaVo	Everest	Residue-free cauterizable resin for LWT
CAD-Temp Block	Vita	Cerec 3, inLab	Fibre free acrylic polymer with micro-filler for long term temporary and partial full crowns and FDPs upto 2 pontics
Everest C-Temp	KaVo	Everest	Fibre reinforced acrylic polymer with micro-filler for long term temporary partial and full crowns and FDP frameworks, requiring an additional veneering
DC-Tell	DCS	DCS	Fibre reinforced acrylic polymer with micro-filler for long term temporary partial and full crowns and FDP frameworks, requiring an additional veneering
Zeno Pro Fix	Wieland	All Zenotec	Polymer for full contour long term provisionals
Procera All Ceram	Noble Pharma	Procera Ceram	pre-sintered and post-sintered, Zirconia block for Crowns and FDPs
LAVA Frame	3M ESPE	LAVA ceram	pre-sintered and post-sintered, Zirconia block for Crowns and FDPs

newer and more esthetic restorative procedure. However, current CAD/CAM technology is expensive but it still makes a significant place in today's dentistry. In coming years, advancements in CAD/CAM systems would have eliminated conventional methods and metal free dentistry is expected. The objectives of dental restoration have extended, all patients demand for more esthetic and comfortable restoration, rather than to maintain their oral function only. So CAD/CAM technology is expected to show more development and help in the fabrication of even more precise and esthetic restorations in future. In dentistry CAD/CAM technology will contribute greatly to rehabilitate the patients in future.

8. CONCLUSION

The advancements in CAD/CAM technology have increased the scope of its application in various industries. Initially, when CAD/CAM was introduced in dentistry, dental CAD/CAM system were restricted only to fabricate inlays, onlays, and single unit crowns but over the past few years, CAD/CAM have shown and proved their utility in restorative, prosthetic and pre-surgery dentistry. Dental CAD/CAM systems allow the application of newer high strength biomaterials with adequate esthetic quality. Expectation of metals free dentistry would have been possible, if innovations and constant advancements in CAD/CAM technology will continue.

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